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Title: Phloem transport under drought

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Phloem transport under drought

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NNSA
National Nuclear Security Administration

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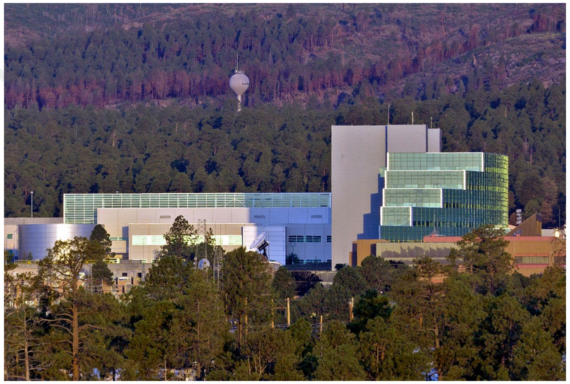

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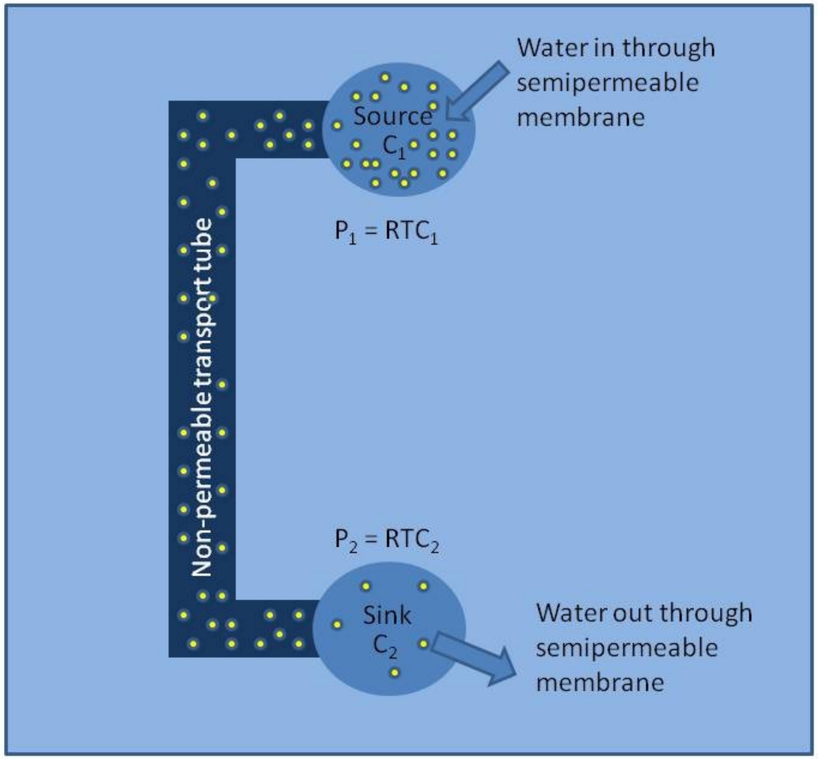
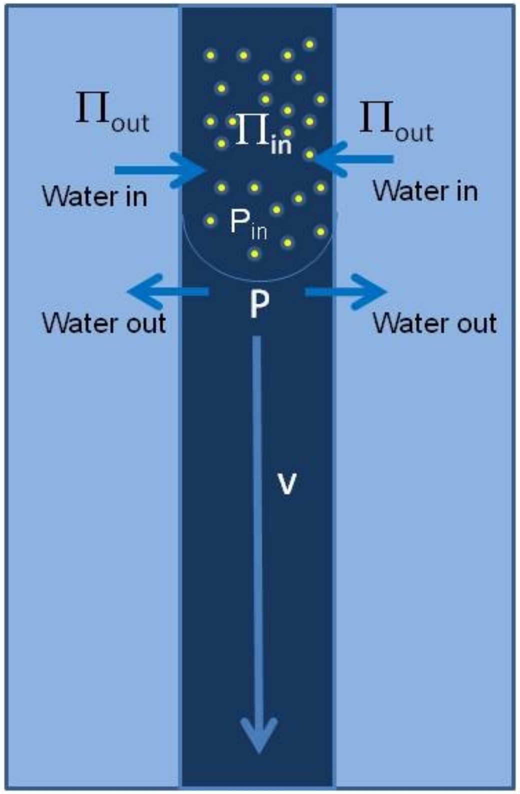
Different ways of building up phloem

Non-permeable conduits walls



Semi-permeable conduits walls

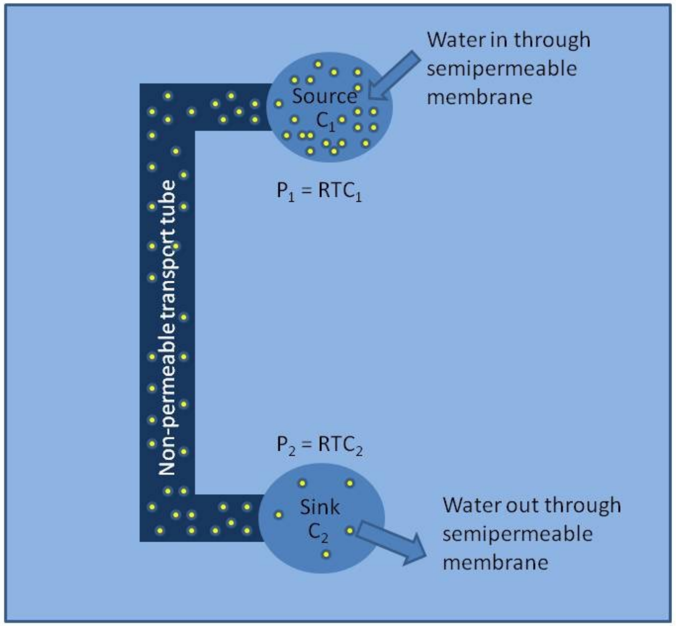


Sevanto, J. Exp. Bot 2014

Pros and cons

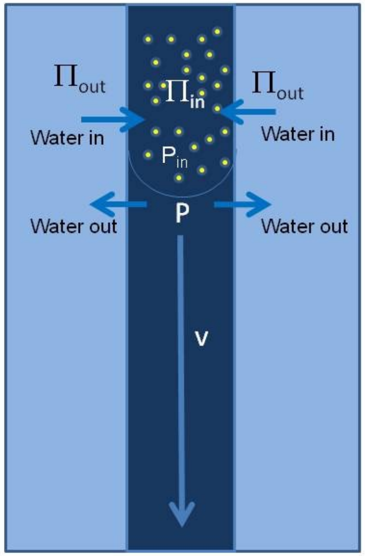
Non-permeable conduits walls

-Phloem relatively isolated from the xylem
-Less prone to turgor loss during drought
-Flow driven by vertical pressure gradient



Semi-permeable conduits walls

-Phloem well connected to it's surroundings
-Less prone to viscosity build-up during drought
-Flow driven by horizontal pressure gradient



Münch number

Fluid viscosity according to Morison 2002

$$\eta = \eta_0 e^{\frac{a\Psi}{1-b\Psi}}$$

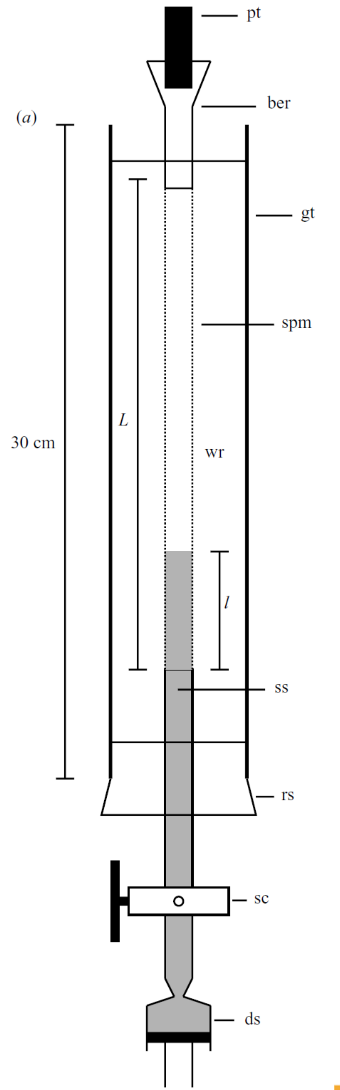
Radial permeability from Sevanto et al. 2011

$$Munch\ number = \frac{16\eta L^2 L_p}{r^3} = \frac{radial\ conductance}{axial\ conductance}$$

Jensen et al. 2009

Conduit size from x-ray tomography measurements

Scalable experiments



Viscosity and permeability varied

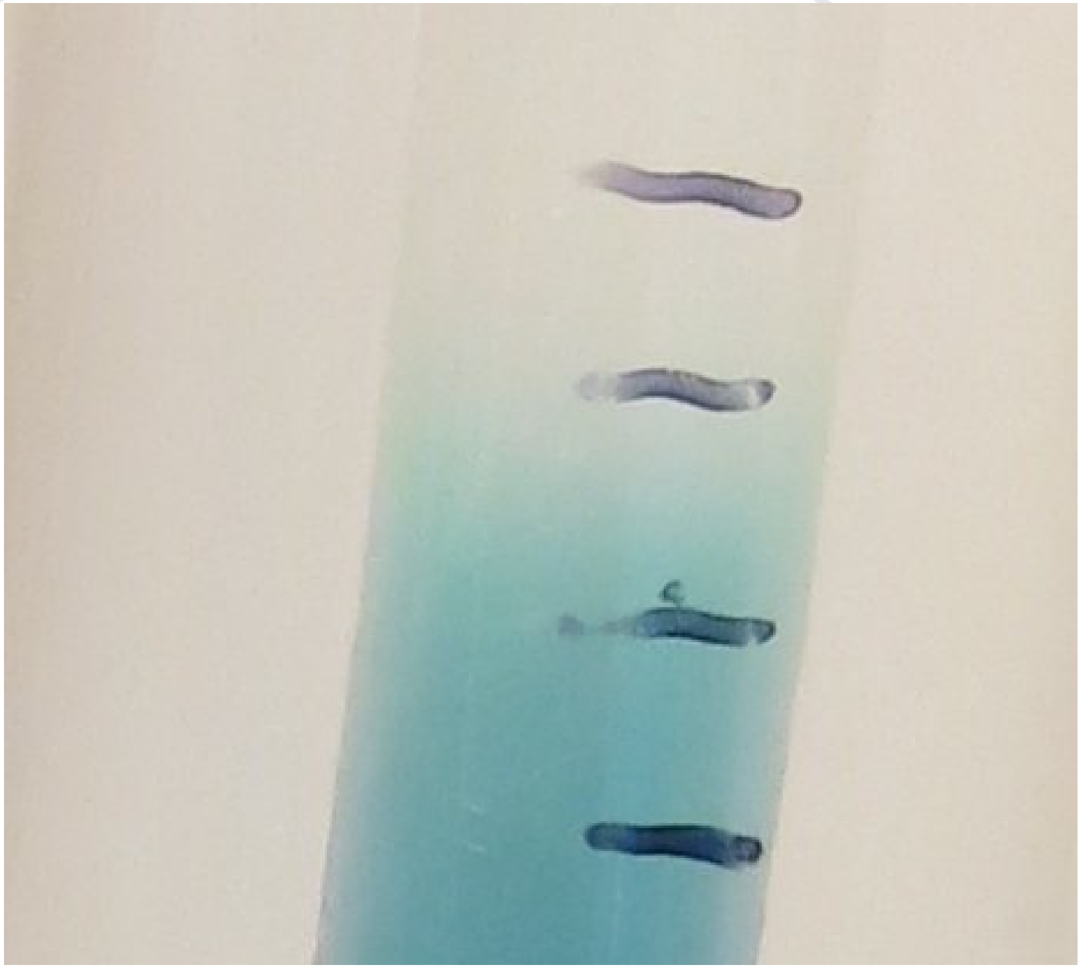
$$Munch\ number = \frac{16\eta L^2 L_p}{r^3}$$

Munch number range 10^{-11} – 10^{-8}

Membrane Thermo Fisher “Snake Skin” dialysis tube
Diameter 16mm, length 40cm

Jensen et al. 2009

Do we have this resolved?



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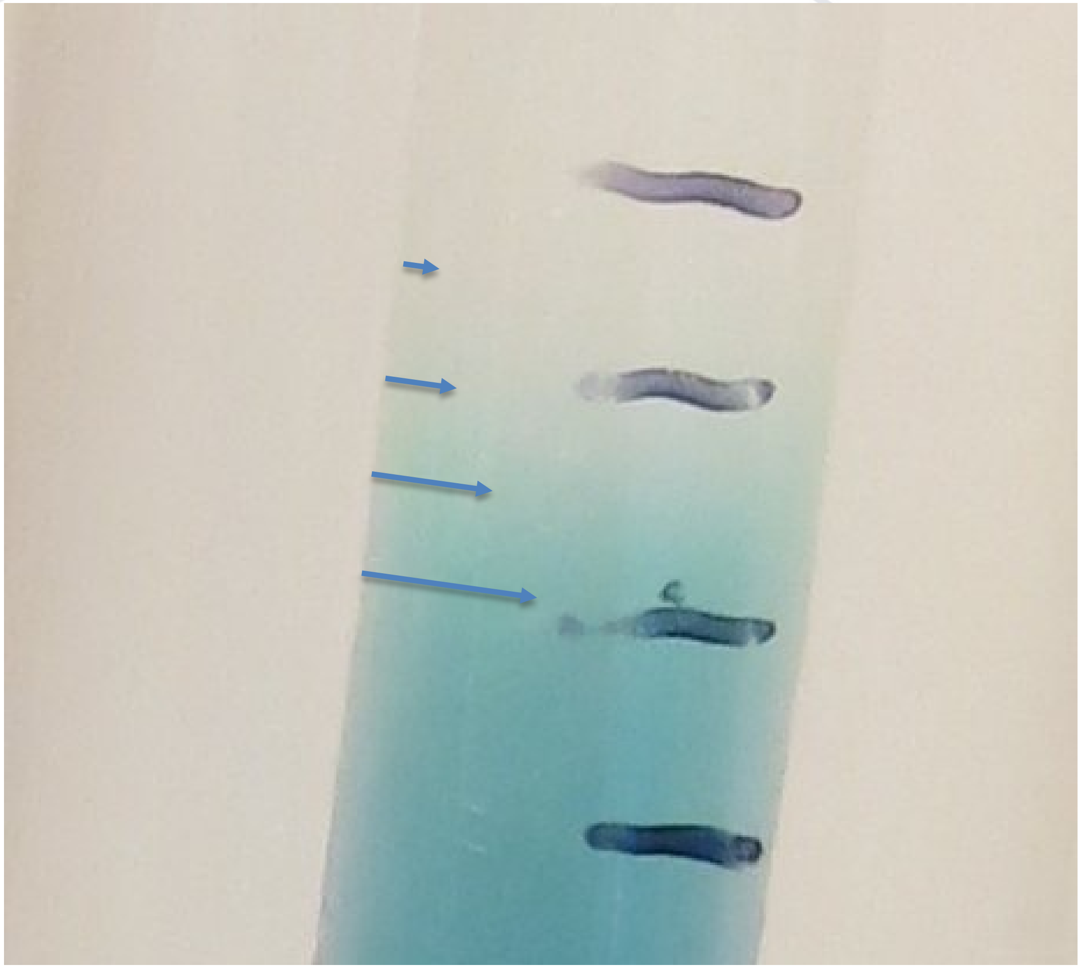

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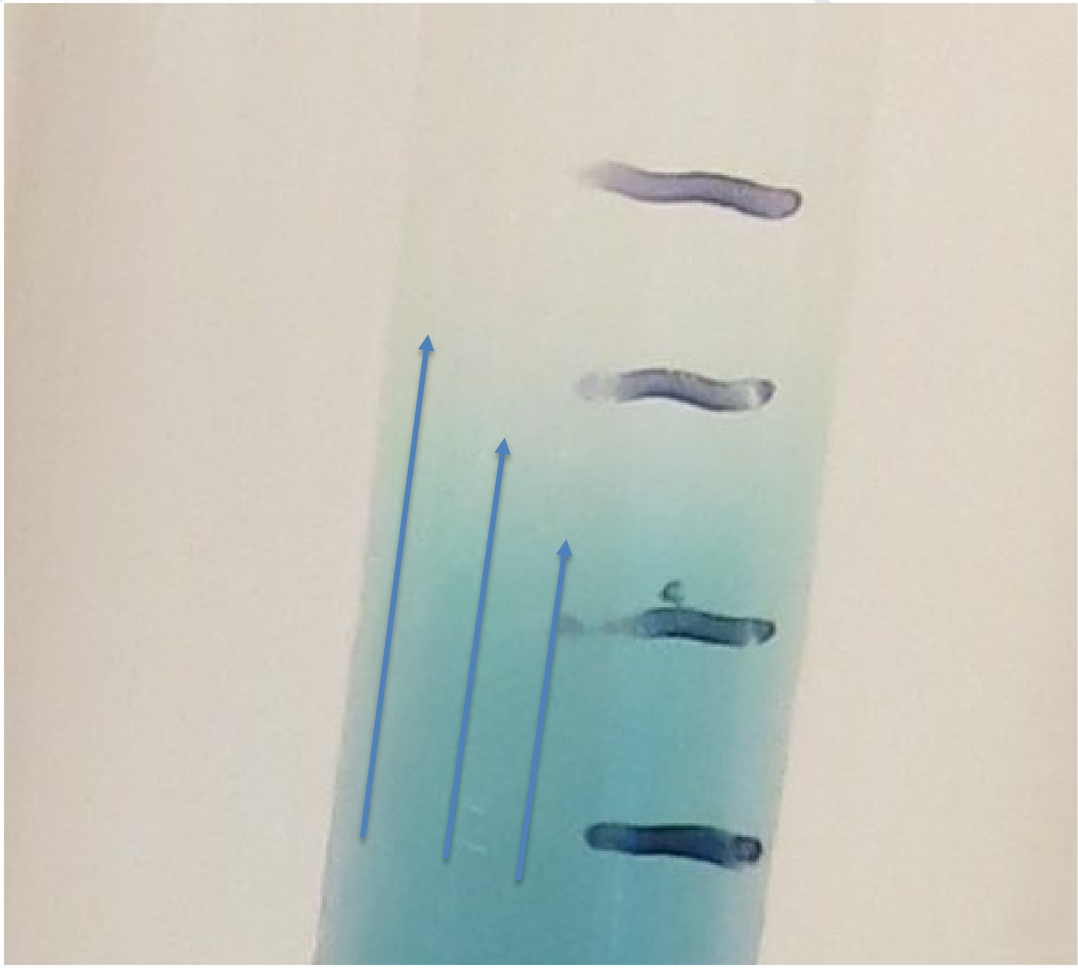
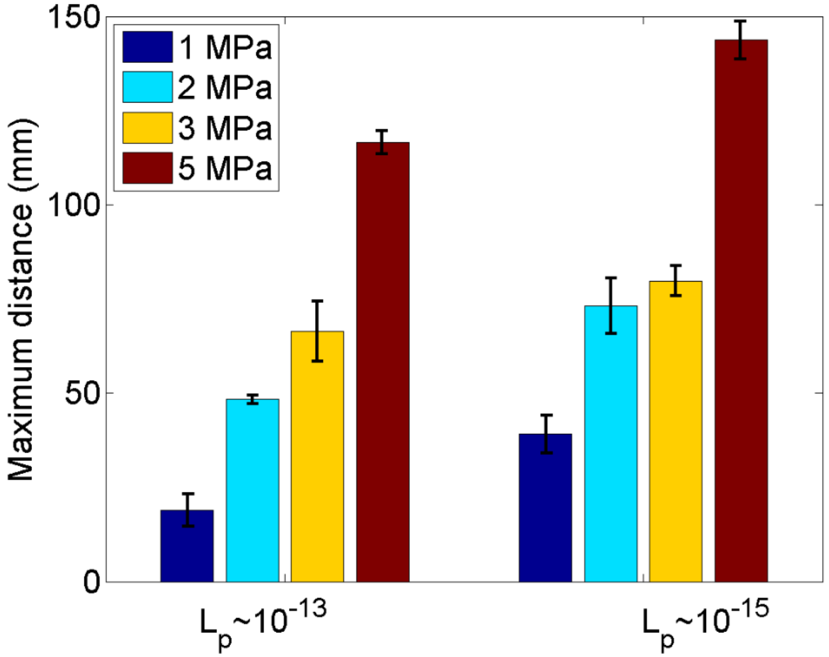
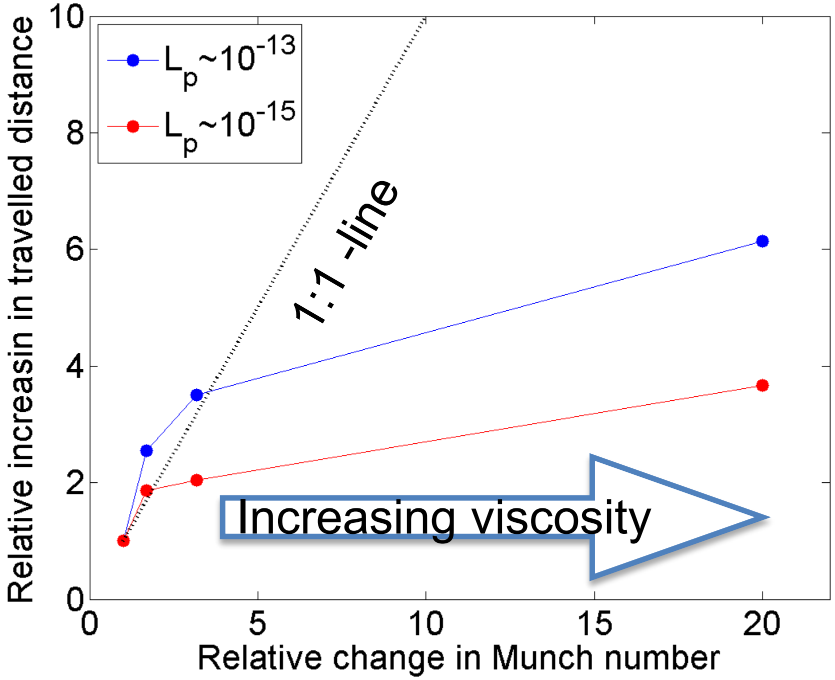


What does radial flow do?

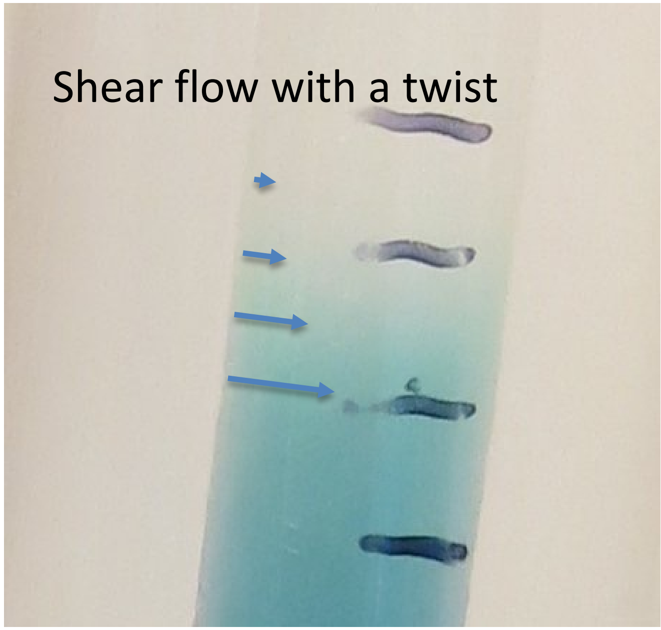




The more permeable the conduits, the more frequent "loading zones" need to be to maintain constant flow rate.

What might radial in flow do?

Taylor dispersion: An effect in fluid mechanics where a shear flow can increase diffusivity of species.



Nakad M, Witelski T, Domec J-C, **Sevanto S,** Katul G. 2021. Taylor dispersion in osmotically driven laminar flows. *Journal of Fluid Mechanics* 913 http://dx.doi.org/10.1017/jfm.2021.56.

What does radial flow do to Taylor dispersion?

-Instead of increasing the longitudinal transport like in non-permeable tubes, outcome depends on Pe_r

-We need to consider high and low Munch number and high and low Pe_r separately

L=2r for radial flow

$$Pe = \frac{advective\ transport}{diffusive\ transport} = \frac{Lu}{D} = Re\ Sc$$

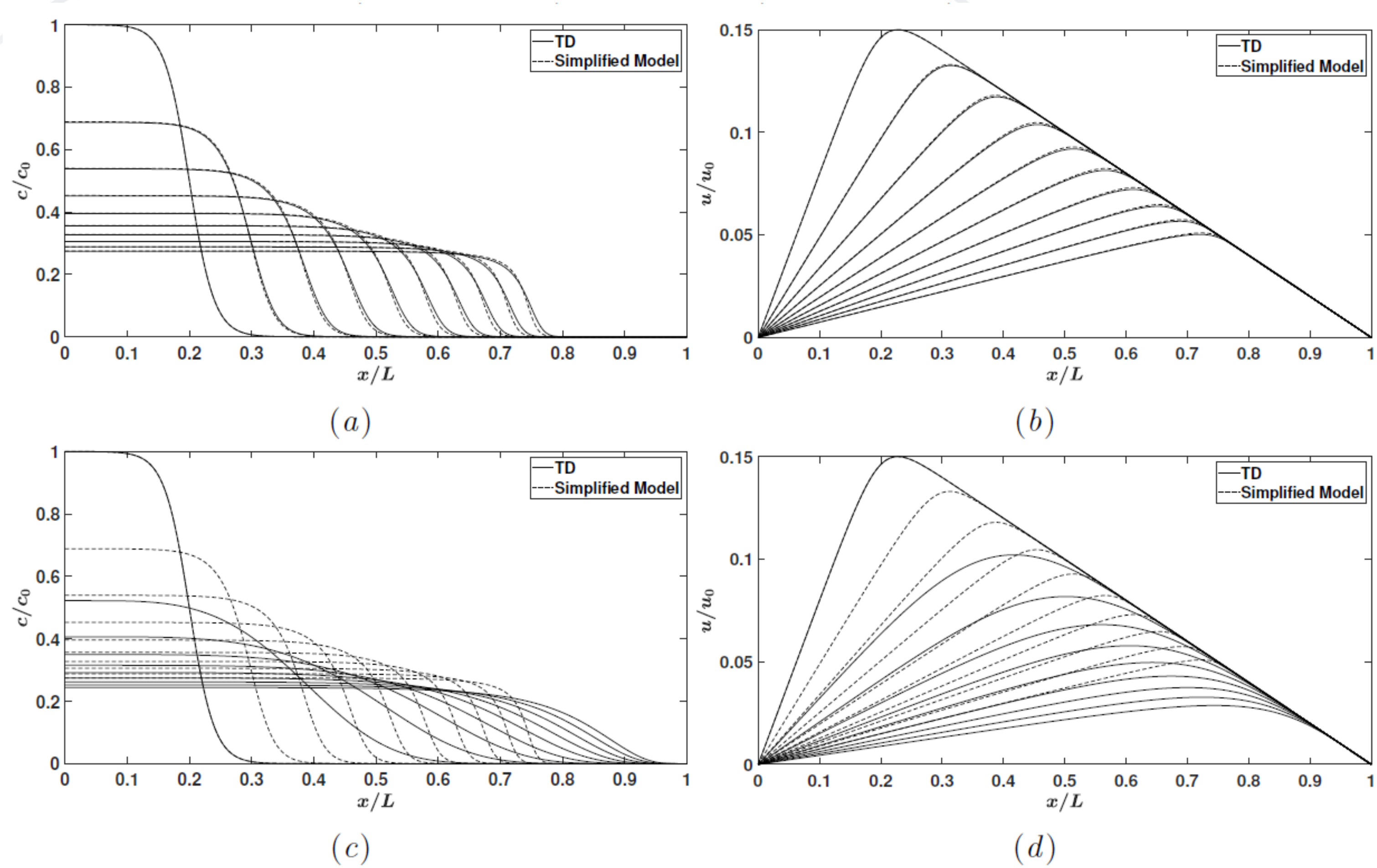
Assumption: Re<<1 but advective transport doesn't need to be small because Sc>>1

Increased sugar flow rates

Low Munch number (low radial conductance)

Low Pe_r
Diffusion
dominates

High Pe_r
Advection
dominates



Increased sugar flow rates

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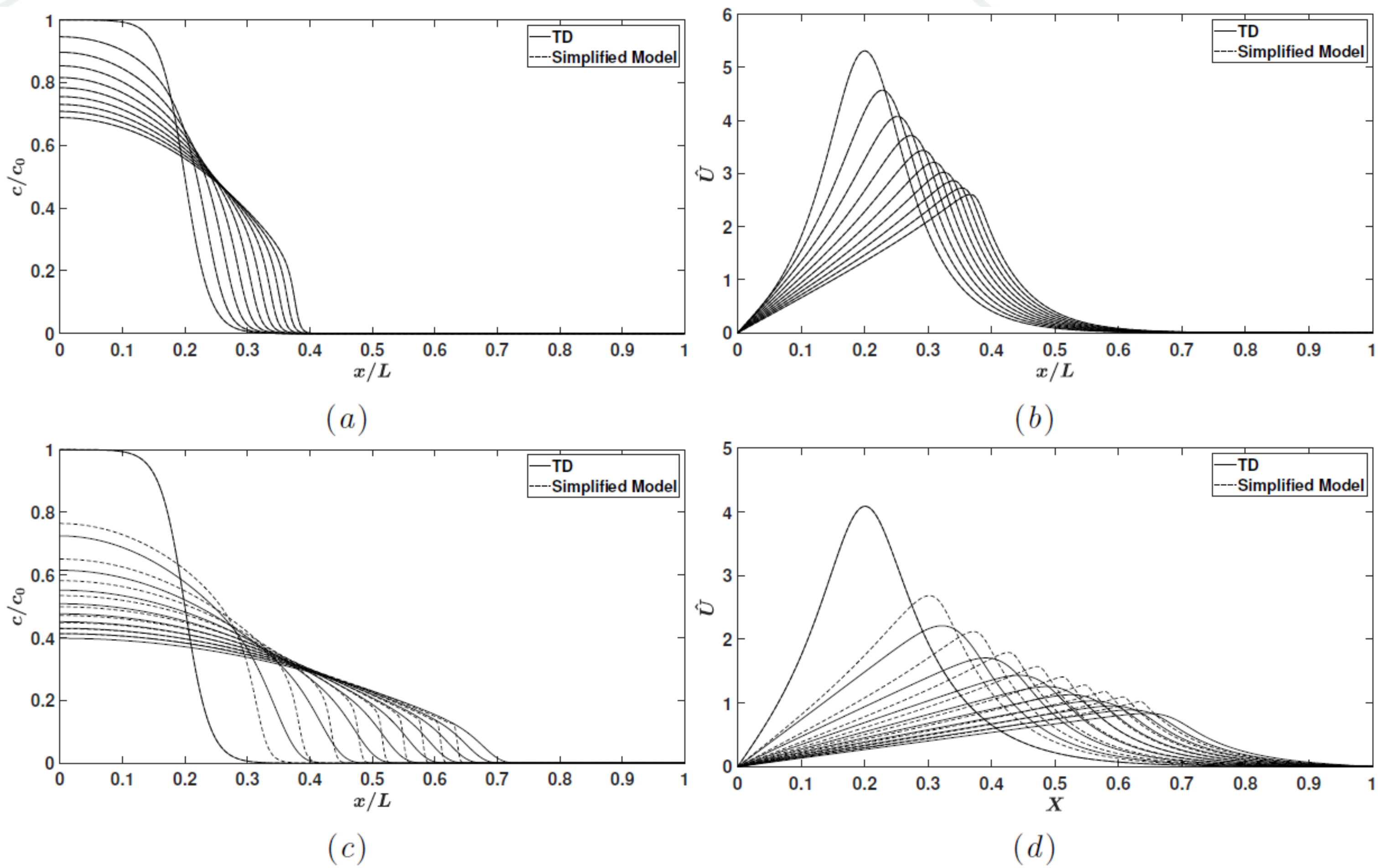
High Munch number (high radial conductance)

Low Pe_r
Diffusion dominates

High Pe_r
Advection dominates



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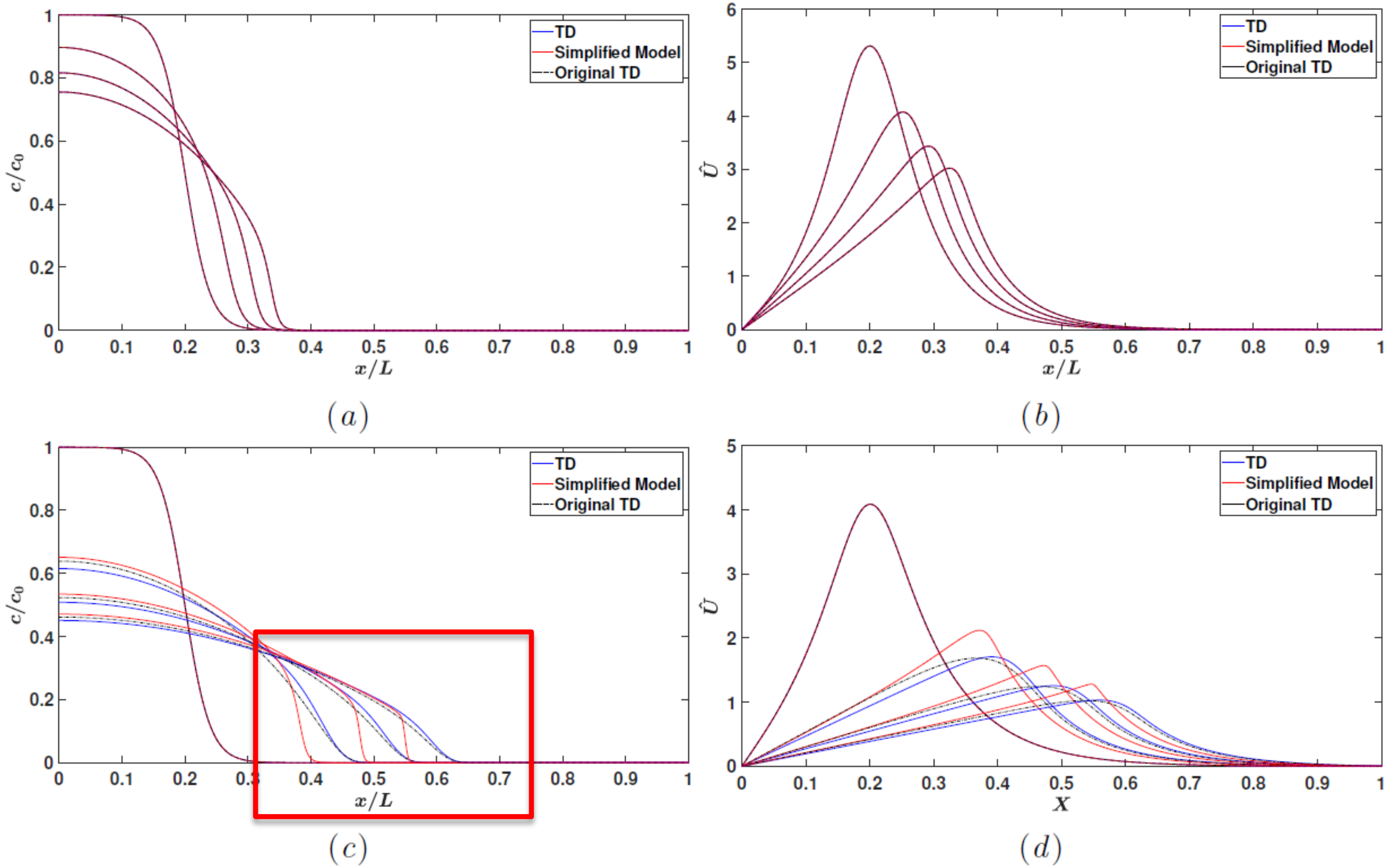
If we assume that v<<u (Hagen-Poiseulle averaging) at high Munch number

Low Pe_r
Diffusion dominates

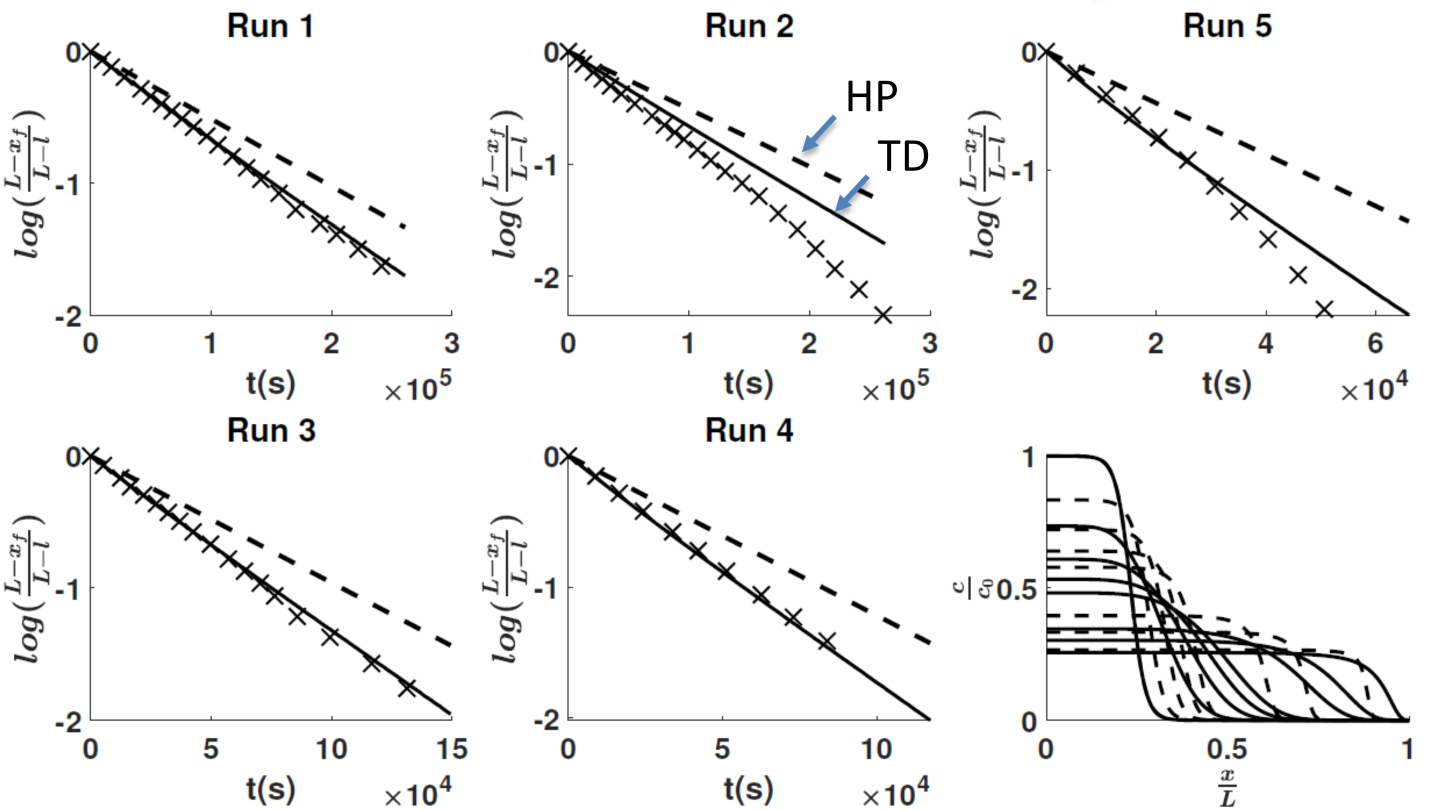
High Pe_r
Advection dominates

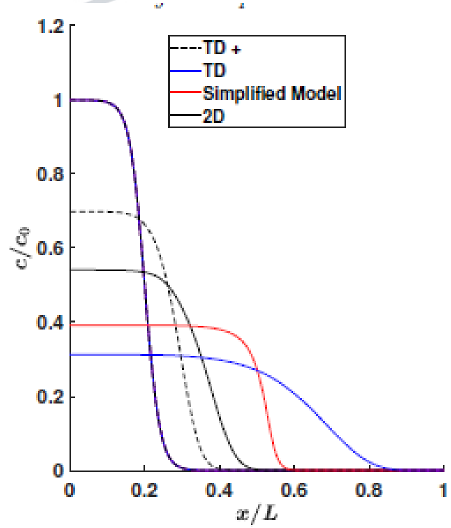


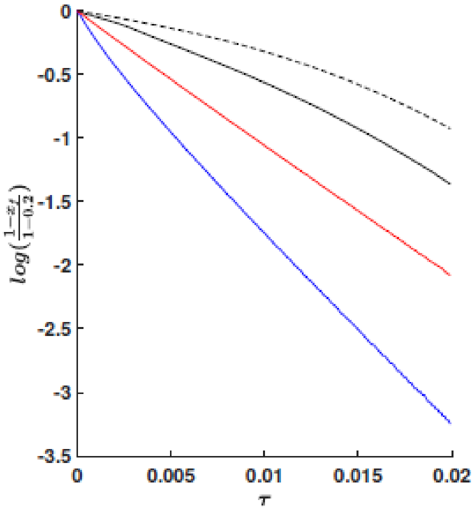
Comparison between Hagen-Poiseulle averaging, Taylor dispersion and experiments

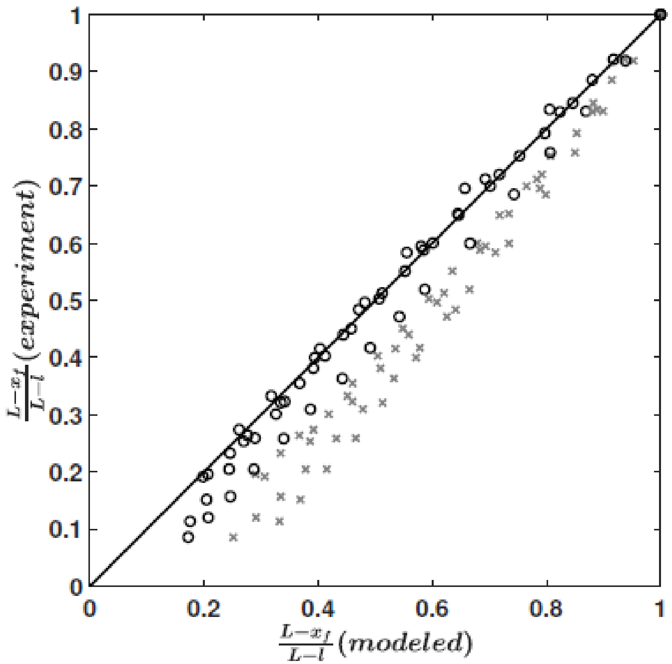
Experimental runs from Jensen et al. 2009; M increases with run number

Sugar front position




TD +
TD
Simplified Model
2D
c/c_0
x/L


$log(\frac{1-x_f}{1-0.2})$
τ


$\frac{L-x_f}{L-l}(experiment)$
$\frac{L-x_f}{L-l}(modeled)$